HARVARD EDUCATIONAL AND SCIENTIFIC REVIEW

International Agency for Development of Culture, Education and Science

Vol.2. Issue 2 Pages 44-52.

10.5281/zenodo.7181271

Harvard Educational and Scientific Review
International Agency for Development of Culture, Education and Science
United Kingdom
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Har. Edu.a.sci.rev. 0362-8027
Vol.2. Issue 2 Pages 44-52.

10.5281/zenodo.7181271

ANALYSIS OF THE INFLUENCE OF THE PROPERTIES OF OIL PRODUCTS ON THE PERFORMANCE OF BELT CONVEYOR GUIDE ROLLER MECHANISMS

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Abstract: The need to clarify the coefficients of use for modern lubricants developed by domestic and foreign industrial enterprises is justified when calculating the periodicity, reliability and resistance to rotation of belt conveyor guide roller mechanisms. For this, it is necessary to study the analysis of the effect of lubricants on the mechanism, taking into account various loads and rotation frequencies during the operation of the belt conveyor. Taking into account these tasks, in the analysis of experimental studies of the components that resist the movement of the belt along the pairs of belt conveyor roller mechanisms, the influence of the degree of filling of the bearing with lubricants, the design of protective covers and the ambient temperature during the work process were determined.

Keywords: conveyor, roller, bearing, support, mechanism, material, plastic oil, belt, resistance, rotation frequency

INTRODUCTION

Belt conveyors are one of the most important means of transportation in mining enterprises. Considering that 40-70% of the total cost of transportation of minerals from open pits is spent worldwide, it is necessary for mining enterprises to create and implement new improved designs of belt conveyors with high efficiency.

The use of new types of plastic lubricants used in belt conveyor guide roller mechanisms is considered one of the important tasks to review the scientific research work on determining the resistance to belt movement caused by belt element sliding bearings used instead of roller bearings. In the past, large-scale scientific and practical research works are being carried out in our republic and in foreign countries

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on the use of new types of plastic lubricants used in belt conveyor guide roller mechanisms.

LITERATURE REVIEW

In this regard, the world's leading scientists, including L.G. Shakhmeister, V.G. Dmitriev, V.I. Galkin, V.P. Dyachenko, A.A. Titov, in modern scientific research centers on the effect of plastic oils on the belt conveyor and its components they are conducting a number of scientific and practical researches. L.Ya. Perel and A.A. In his scientific research, Filotov worked on calculating the performance of bearing parts, taking into account the effect of plastic lubricants.

In the analysis of experimental studies of the components that resist the movement of the belt along the pairs of belt conveyor guide roller mechanisms, the effect of the degree of filling of the bearing with lubricants, the design of protective covers and the ambient temperature during the operation was determined [1].

We can say that the structure of protective caps, the type of lubricants, the rotation speed of the mechanism, various loads and ambient temperature influence the decrease in the periodicity and durability of roller mechanisms. The increase in the rotational resistance of the guide roller mechanism causes a change of 15 to 20% of the total resistance to the movement of the conveyor belt. In turn, it is of great interest to study the effect of lower temperatures on the rolling resistance of belt conveyor guide roller mechanisms [2].

RESULTS

It is important to observe the influence of the level of lubricant filling of the two-row trapezoidal grooves opened on the inner surface of the proposed belt element sliding bearing, as well as the movement of the protective cover details of the new design used in the guide roller mechanism. When the belt element sliding bearing is filled with 60% lubricant, the lubricant has no effect on the protective caps, because the lubricant only spreads along the inner surface of the axis and the part. Of course, this situation reduces the movement resistance of the belt conveyor (Fig. 1).

Har. Edu.a.sci.rev. 0362-8027
Vol.2. Issue 2 Pages 44-52.

10.5281/zenodo.7181271

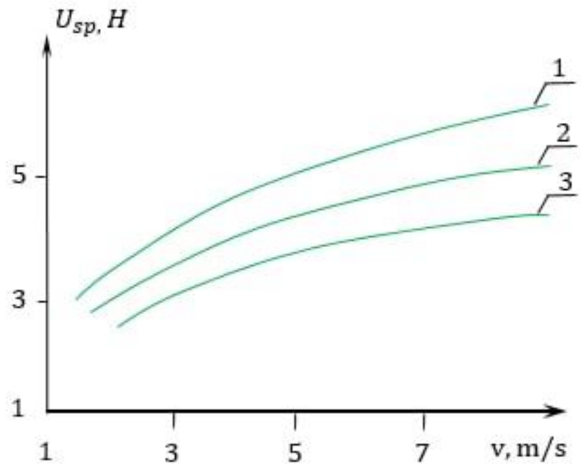

Figure 1. Graphs of the dependence of oil supply and external rotational speed of the sliding bearing with a belt element on the rolling resistance of the roller mechanism, 1, 2, 3 respectively 45, 30, 10%.

Depending on the operation of the guide roller mechanism, after some time, the temperature rises in the sliding bearings with a belt element. As the ambient temperature Θ_{OX} decreases, the level of lubricant viscosity increases, as a result, the temperature Θ_Y increases in the protective labyrinth covers (Fig. 2).

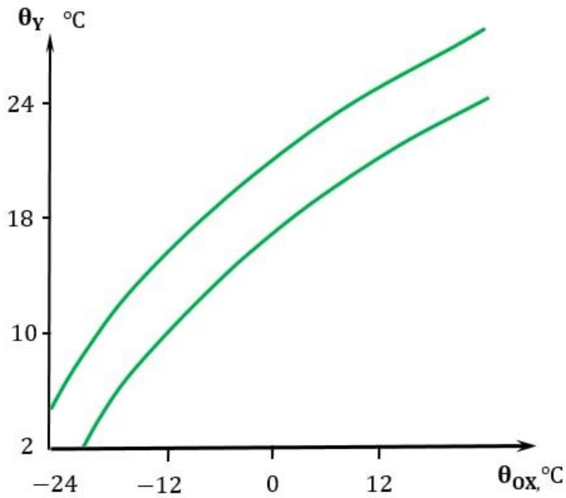

Figure 2. Temperature dependence of protective covers of guide roller mechanisms on the working area

In this case, it is recommended to consider the effect of the average temperature coefficient of the ambient temperature:

$$k_0 = \frac{U_{BP}(\Theta)}{U_{BP}(30^0C)} ; \quad (1)$$

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Also, the effect of the type of lubricant on the rotation speed of the roller mechanism was determined using the coefficient k_0. This is calculated according to the following formula:

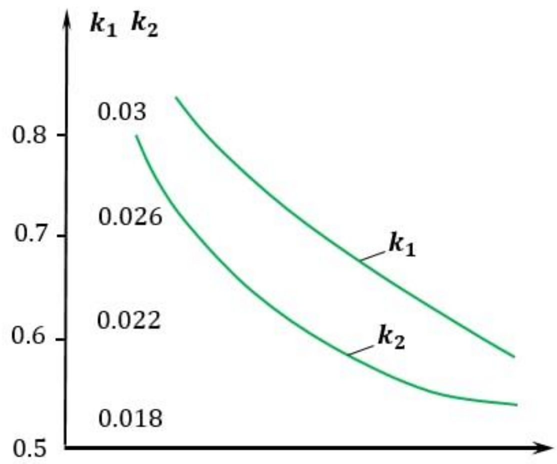

Figure 3. Dependence of the coefficient $k_1 - k_2$ on speed

$$k_\Theta = exp(k_1 - k_2\Delta), \quad (2)$$

where Δ – is the difference between internal and external temperature; $k_1 - k_2$ coefficients determined on the basis of data obtained as a result of experimental studies (Fig. 3).

The following formula is given for calculating the rolling resistance of guide roller mechanisms:

$$U_{BP} = (a + bv)k_\Theta + C_O F + C_P P. \quad (3)$$

Most of the previous scientific and research work was focused on the selection of lubricants for belt conveyors operating in northern conditions with an ambient temperature of +40 to – 45 °C [3, 4].

Therefore, the requirements for belt conveyor guide roller mechanisms and their lubricants are increasing. The reason for the increase in the coefficient of resistance to the rotation of the guide roller mechanisms is considered to be due to the quality of the lubricants, which requires research and development to create special lubricants. When the temperature changes within the limits indicated above, the belt conveyor guide roller mechanisms operate without significant changes in rolling resistance coefficients.

Typically 30 to 50% of the total resistance to belt movement is the resistance to rotation of the belt conveyor guide roller mechanisms. The amount of resistance to rotation of guide roller mechanisms depends on the design of protective covers, the type of lubricants, the load, the speed of rotation and the ambient temperature. At low temperatures in the mining industry, belt conveyors have the greatest effect on the

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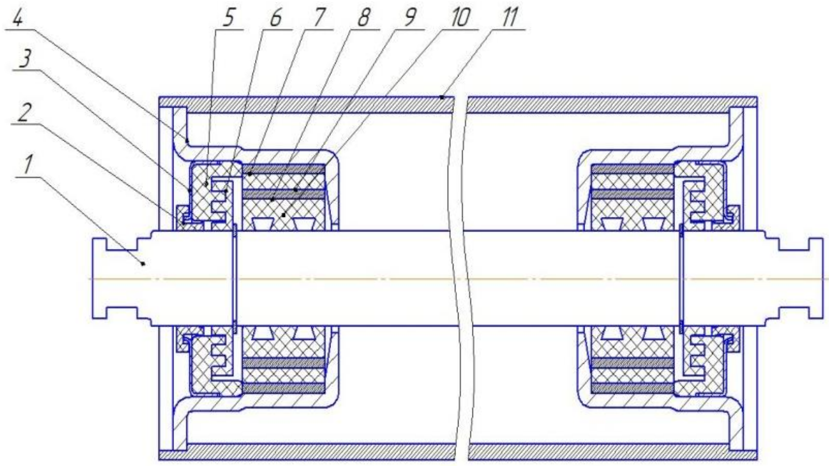
resistance to rotation of the guide roller mechanisms when running after a long stop. When the temperature drops, the lubricant in the guide roller mechanisms thickens, which causes the power consumption of the conveyor to increase, making it difficult for the conveyors to start.



1 – axle, 2 – labyrinth bushing, 3 – cover, 4 – stub, 5 – labyrinth cover[1], 6 – labyrinth cover[2], 7 – ring[1], 8 – ring[2], 9 – belt element, 10 – sliding support (graphitocaprolon), 11 – shell

Figure 4. Roller mechanism (Belt conveyor)

Several studies have been conducted on the use of SIATIM-203, Litol-24 and Universal oil solidol (cold-resistant) lubricants on the inner surface of sliding bearings with belt elements in guide roller mechanisms. Determination of the resistance to the rotation of the guide roller mechanisms was carried out in special scientific research laboratory stands. The rotation speed and tilt angles of the roller mechanisms by taring at different loads made it possible to measure the value of resistance to this rotation.

The sliding bearing with the belt element and the protective labyrinth covers in the belt conveyor roller mechanism were made at the «Machinery Plant» PU belonging to the Navoi mining and metallurgical combine state enterprise. Tests to determine the resistance to rotation of belt conveyor guide roller mechanisms were conducted in indoor and outdoor conditions at the Central Scientific Research Laboratory of the State Enterprise of the Navoi Mining and Metallurgical Combine, with an ambient temperature of +45 to – 45 °C [5, 6].

Based on the results of processing the obtained data using the method of mathematical statistics, the following relationship was determined for calculating the resistance to rotation of the guide roller mechanisms:

$$F_{BP} = \frac{0{,}152}{d_p}\left(ae^{th_H} + P_a + P_G\right), кгс, \qquad (4)$$

where d_P –roller diameter, mm; $a = \psi n^{-a}$ – coefficient; n – speed of rotation of rollers, rev/min; $b = 0{,}1(0{,}9031 - lg\,\psi + alg\,n)$; t_H – ambient temperature, °C; $P_n = n(\lambda + \varepsilon G)$ – taking into account the speed of rotation, the component of resistance to the rotation of the rollers, rc;$\psi, a, \varepsilon, \lambda$ – the value of proportionality

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coefficients is shown in table 1; $P_G -$ component of resistance to rotation of the roller from the load, rc; $G -$ the load on the roller, kgs.

In scientific and research work on determining the reliability of guide roller mechanisms, issues of selection of protective caps, abrasive and frictional rotational parameters in sliding bearings with belt elements were considered [7, 8].

Table 1

Type of lubricant	Coefficient values			
	ψ	a	ε	λ
BNZ-3 GOST 5.1343-72	310	0,1870	$2{,}9{\cdot}10^{-3}$	0,107
1-13 GOST 1631-61	316	0,211	$2{,}53{\cdot}10^{-3}$	0,0332
BNZ-3M GOST 5.1343-72	171	0,2180	$1{,}443{\cdot}10^{-3}$	0,1540
Severol (experimental)	186,5	0,231	$1{,}26{\cdot}10^{-3}$	0,104
SIATIM-203 GOST 8773-63	130	0,24	$1{,}12{\cdot}10^{-3}$	0,104
Universal oil (solid oil (solidol)) GOST 1033-51	207	0,15	$2{,}53^{-3}$	0,309

The effect of lubrication properties on the operation of sliding bearings with a belt element is used to determine the conditions of use of oil layers in the contacts of heavily loaded rolling surfaces, taking into account the elastic-dynamic theory of lubrication [9, 10].

The minimum thickness of the oil layer in frictional contact with the inner ring of sliding bearings with a belt element is determined by the formula (5):

$$h_0 = \frac{0{,}1^{0{,}6}(\eta v)^{0{,}7}}{(\sum p)^{0{,}43}(\frac{Q}{l_W})^{0{,}13}}\left(\frac{E}{1-\varepsilon^2}\right), \quad (5)$$

where k – is a parameter taking into account the dependence of pressure on viscosity, (usually k 0.01 ÷ 0.02), mm^2/N; η – dynamic viscosity at working pressure, $mPa{\cdot}s^2$; v – low speed on the surface of the guide roller mechanism, m/s; $\sum\rho$ – the sum of the curves of the contacting surfaces, mm^{-1}; Q – load on the roller, N; lW – effective length of the roller, mm; E – modulus of elasticity, MPa; ε is Poisson's ratio.

For bodies made of plastic materials (E = 2.08·105MPa, ε=0.3) takes the form of the formula for calculating the minimum thickness of the oil layer (*mkm*)

$$h_0 = \frac{0{,}145^{0{,}6}(\eta v)^{0{,}7}}{(\sum p)^{0{,}43}(\frac{Q}{l_W})^{0{,}13}}\left(\frac{E}{1-\varepsilon^2}\right), \quad (6)$$

As can be seen from equation (6), changes in oil viscosity and rotation speed affect the lubrication layer thickness more than changes in load.

Formulas (5) and (6) give the size of the lubrication layer in the case of linear contact.

When calculating the resistance of sliding bearings with a belt element lubricated with a lubricant with a kinematic viscosity at operating temperature $\upsilon \geq 12$ mm^2/s, according to the theory of elastic dynamic lubrication at $nD0 \geq 10000$, the conditions necessary for the formation of an oil layer in contact with the inner surface of the sliding bearings with a belt element it is recommended to take into account.

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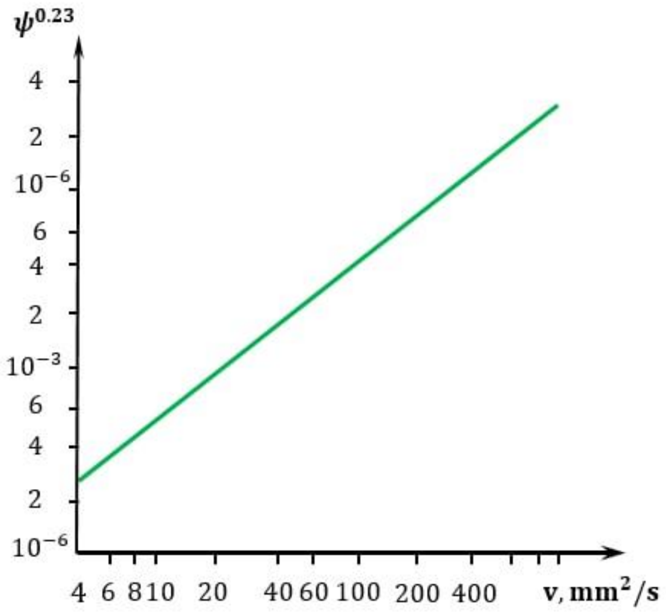

Figure 5. Determination plot for a given *v* – kinematic viscosity of lubricant $\psi^{0,73}$

The coefficient Λ describing these conditions is determined from.

$$\Lambda = K_{\Lambda} D_0 (\Psi n)^{0,73} P_0^{-0,09} \quad (7)$$

where K_{Λ} – is a ratio depending on the type of sliding bearings with a belt element; D_0 – is the average diameter of sliding bearings with a belt element, *mm*; Ψ – the ratio depending on the viscosity of the oil material, v; (the value $(\Psi n)^{0,73}$ is determined based on the kinematic viscosity from the diagram in Fig. 5) P_0 – is the equivalent statistical load of sliding bearings with a strap element, *N*; n is the rotational frequency of sliding bearings with a belt element.

At $\Lambda = 0,8 \sim 3,5$, the lubrication conditions are satisfactory for most types of bearings. However, for bearings with relatively large sliding friction losses, it is desirable to have $\Lambda \geq 1,5$. When $\Lambda < 0,8$, bearing lubrication is not effective enough, and in this case, oil with high viscosity should be used.

At $\Lambda \geq 4$, the conditions for the formation of an oil layer in the bearings are provided, there is a complete separation of the pad surfaces in the bearing with an oil layer. In such cases, the operating periodicity of the bearing is determined using several formulas. The results of the theoretical and experimental studies considered above used previously obtained coefficients for lubricants used in the 70 s of the last century to determine the forces of resistance to the movement of the mechanism and to determine the operational reliability of the roller mechanisms of belt conveyors. At the same time, it is an urgent scientific task to determine these coefficients for modern lubricants used in bearing assemblies of roller mechanisms of belt conveyors of mining enterprises.

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The main indicators of the operational characteristics of modern lubricants used in domestic and foreign industrial enterprises are presented in the article.

Plastic lubricants are paste-like lubricants obtained by mixing solid thickeners with liquid oils or synthetic oils. These lubricants are significantly different from liquid meniral oils. According to their mechanical properties, plastic oils occupy an intermediate position between solid and liquid. Under the influence of low shear loads, plastic lubricants act as solids, and at high shear loads they act as liquids, that is, they become liquid [8].

The main advantages of the ratio of plastic oils to liquid oils: It does not lose its properties in non-hermetic friction units, that is, it is distinguished by its high efficiency at low and medium loads. Using plastic oils instead of conventional lubricants reduces the mass of the friction unit by 25%. The disadvantages of ordinary lubricants are manifested in the deterioration of the ability to cool the friction surfaces, and the timely lack of oils in the section of the friction zone.

Lubricants consist of two components:

– oil base (synthetic, minimal, vegetable or other oils);

– solid thickener (with and without soap).

Plastic oils usually contain structural stabilizers and additives, and often various substances (graphite, molybdenum disulfide, oxides, etc.). Thickeners form a solid structural grid containing oil.

DISCUSSION

Thickeners determine the production structure of oils and their quality level in general. In terms of the composition of the produced lubricants, our country lags far behind the European countries and the USA, where lithium lubricants are the main ones. The share of lithium oils in the total volume of their production is 60 % in the USA, 70 % in Western Europe, and 24 % in Russia. The basis of the assortment of oil materials produced in Russia (about 45 %) is old hydrated calcium oils, the production of which, for example, in the USA, does not exceed 4 %. The production of sodium and sodium calcium lubricants in our country is about 31 % of their total production volume. These oils have satisfactory performance characteristics. They are used in the temperature range from – 30 to + 100 °C.

The main direction to improve the quality of modern lubricants is the use of synthetic oils as an oil base in the use of soapy lithium condensers. Wide use of various additives expands and improves the range of action of lubricants. The main characteristics of modern universal lubricants are very close to each other, which complicates the task of choosing the most suitable one in accordance with the requirements for the main performance indicators of lubricants used in the bearings of guide roller mechanisms of belt conveyors of mining enterprises.

CONCLUSION

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Based on the solutions of the above graphs and the formulas for their calculation, in the «Scientific research laboratories» of the mining industry enterprises, in the scientific research laboratories of the technical higher educational institution, in the selection of a number of domestic and foreign oils and in determining the forces of resistance to movement for them, and in determining the reliability of the bearings of the roller mechanisms of belt conveyors it is important to carry out scientific research on the task of determining the used coefficients.

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